POST-GLACIAL HISTORY OF BOSTON

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CONTENTS.

Introduction.

The time from the close of the Glacial Period, from the melting back of the glaciers which lately covered this region, to the present, is full of interest. For it is this post-glacial time which tells us of our own immediate past; it tells us of the recovery by organisms of the uninhabited glacier-covered lands. It gives us the history of these organisms and through them of the topography and climate of the region. The records of these organisms, in the Boston area, are mainly preserved in the mud deposited here during this time. This mud was partly laid down in shallow fresh-water swamps but mostly in sea-water, in inlets from the ocean. Naturally the majority of these records consist of the remnants of plants, and especially of shells, though there are also one or two records of early man.

One of the earliest persons to make a broad study of the post-glacial fossil shells of Boston was Miss D. L. Bryant (1). This subject formed the theme of her graduating thesis in geology in 1891 at the Massachusetts Institute of Technology; it was pursued under the efficient help of Professor W. O. Crosby. Unfortunately it was never published. Later on during the same year, however, Mr. Warren Upham (3) used Miss Bryant's principal facts and conclusions (for which he gave full credit) in the preparation of a paper on the "Recent fossils of the Harbor and Back Bay, Boston." This is an excellent little pamphlet full of information concerning these Post-Pleistocene fossils. In 1903 Professor W. O. Crosby (2) discussed the bed rock of this area with reference to the pre-glacial drainage, the deposition and subsequent erosion of the blue glacial clay and the deposition of the silt.

In the preparation of the present paper we have drawn freely from these three pamphlets. The notes and the additions here made to

the lists of species from Muddy River, Charles River and City Point, as published by Warren Upham, are based on specimens in the Boston Society of Natural History and the Massachusetts Institute of Technology, unless otherwise stated; these were largely collected by the late Professor Henry W. Haynes. The principal original contribution in this paper, however, regards the Back Bay region of Boston. The recent excavation of the Boylston Street Subway* of the Boston Elevated Railway Company gave many sections down through the Post-Glacial mud to the Glacial clay. These sections and their included organic remains proved so interesting that this record of them was kept.

I wish to express my indebtedness to the following,— to the various officers in charge of the Boylston Street Subway excavations, who were always most courteous and helpful, especially to Messrs. L. S. Stone, J. H. O'Connor, J. T. Frame, and F. H. Eichorn; to Mr. C. W. Johnson, Curator of the Boston Society of Natural History, for giving me opportunity to study the Muddy River, Charles River and City Point fossils in the Society's collection, as well as for identification of some species and aid in the revision of the nomenclature; to Mr. F. N. Balch for permission to make use of his notes upon early colonial records of shell-fish; to Rev. H. W. Winkley for his kindness in comparing our specimens of the Pyramidellidae with those in his large private collection; to Mr. Wm. F. Clapp of the Museum of Comparative Zoölogy for his helpful criticism, and especially for his discovery and description of the minute new species of Vitrinella; to Mr. G. B. Reed of Harvard University for examination of the peat; to Dr. Willoughby, Curator of Peabody Museum, Harvard University, for information concerning the fishweir found in the Boylston Street Subway and for suggestions on the comparison of this wood with that used by early man elsewhere; and to the Bostonian Society for permission to make a copy of the DeCosta map (1775) of Boston and vicinity, now in the Old State House.

The sections are arranged in order from that of Muddy River (section 1) at the west to that of City Point (section 7) at the east (see map).

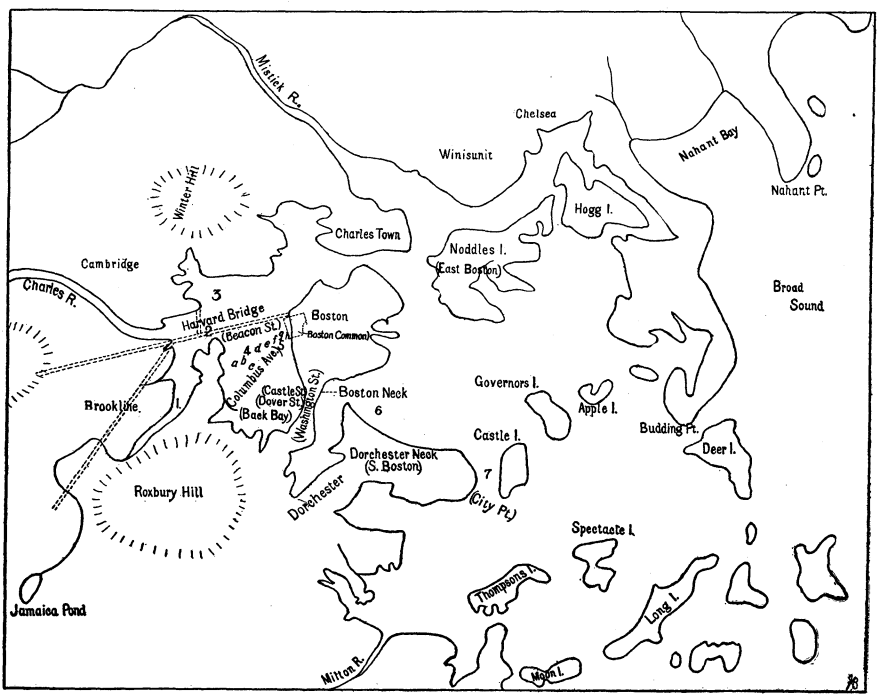
Description of Sections.

1. **Muddy River,** from Brookline northeastward. The collections here were made mostly from a trench, averaging 16 feet in depth, extending along Muddy River from Brookline to Longwood and then

* Completed in 1914.

northeast to Charles River. The generalized section in this region from above downwards is as follows *:—

1. Alluvium, — 5 feet at the Longwood Bridge to 12 feet elsewhere.
2. Peat,— averaging one-foot in thickness, containing stalks



Boston and vicinity in colonial time. The De Costa map, 1775, (reproduced by permission of the Bostonian Society) forms the basis of the above sketch map. The dotted parallel lines, exclusive of those showing Harvard (Technology) Bridge, indicate the dams built by the Boston and Roxbury mill corporation. The numbers 1 to 7 refer to the sections described in this paper.

of swamp plants, leaves of deciduous trees, and some shells,— mostly Modiolus demissus var. plicatulus, embedded in some sand and much mud.

3. Silt,— (no thickness given). Most of the shells noted in the table below occur in this stratum immediately beneath the

* Arranged from Miss Bryant's thesis.

peat bed, crowded thickly together. The shells range almost to the Boston and Albany Railroad station in Brookline; there are none to the southwest of this.

4. Eroded sand plain (a glacial deposit). At the Longwood Bridge the sand plain had been eroded to a depth of 37 feet before the deposition of the five feet of alluvium.

2. **Charles River,** directly east of the Harvard (Technology) Bridge extending between Back Bay and Cambridge. During the dredging here to fill in the shallows on the Cambridge side between the newly constructed wall along the river and the railroad tracks, many shells were found. These shells occurred mostly in the sands and not in the superficial muds. These sands were some ten feet below mean low tide. The height of the tide here, before its obliteration by the dam, was ten feet.

The most conspicuous species are the large and abundant forms of oyster (Ostrea virginica), short-neck clam (Venus mercenaria), long-neck clam (Mya arenaria) and scallop (Pecten gibbus borealis). A small oyster shell is unusual, the average size being 8 by 2.5 inches; one figured by Miss Bryant had a length of 10.5 inches.

During early colonial days (middle of the seventeenth century) an extensive oyster-bank existed here, preventing large boats from going farther up the Charles. (See p. 451).

3. **New Tech Site.** The new site for the Massachusetts Institute of Technology occupies the northeastern angle between Charles River and Massachusetts Avenue. The many bore-holes put down here while the foundations of the new buildings were being planned showed that the solid rock bottom varied much in depth. The following is one of the deeper sections,—

1. Fine and coarse sand, much of it colored green; 35 feet. Unidentifiable fragments of fossils were present in the material brought up by the wash-drill.
2. Soft to stiff blue clay (a glacial deposit); 83 feet.
3. Decomposed bed-rock of slate; 14 feet. The boring stopped in the slate at a depth of 132 feet.

4. **Boylston Street Subway** localities. The sections were made at or very near the junction with the following streets:

a. Fairfield Street. The top of the peat is 18 feet below mean low tide; the peat is 5 feet thick.

b. Exeter Street.— The surface of the street here is 16.5 feet above mean low tide, while the bottom of the peat bed is 15.5 feet below mean low tide.

		Feet
1.	Fill, in blotting out the Back Bay. This fill has taken place mostly since 1868.	16
2.	Gravelly black silt. Few fossils	6
3.	Fine black silt. Many fossils. The middle portion is very full of fossils; the uppermost two feet and the lowest foot contain but few. This silt is a dark-grey (when dry) argillaceous sand with a considerable number of mica scales. The compound microscope shows that very minute sand particles made up fully nine-tenths of the mass; there is merely sufficient clay and carbon particles to give consistency and a dark-grey color to the sediment.	5
4.	Sandy, fresh-water peat	5
5.	Blue sandy clay with some peat. This is the upper edge of the glacial deposit.	1

c. Copley Plaza Hotel, on Copley Square at corner of Dartmouth Street and Huntington Avenue. During the excavations for the foundations Mr. C. W. Johnson obtained, at a depth of 25 to 30 feet below the street surface, Mya arenaria and Macoma balthica, both similar to the Exeter Street forms. The silt in which they occurred was similar in color and composition to that of Exeter Street,— 4b3.

At Dartmouth Street in the Subway the upper ten feet of blue clay (beneath the black silt) was so hard that a pickax could penetrate it only with difficulty; below that it gradually became quite soft. This hardening was probably due to the oxidation of the surface and the deposition of iron as cement upon exposure to air. The presence of ancient gullies in the surface of the clay encountered at various places in the subway also points to this subaerial exposure.

d. Clarendon Street. At a depth of 25 feet below the surface of the street were found,—

Mulinia lateralis c
Macoma balthica c
Gemma gemma c
Ilyanassa obsoleta c

These forms are all like those from the Exeter Street locality and occur in a similar silt.

e. Berkeley Street. Surface of street is about 16 feet above low tide.

Feet

1. Fill, blotting out the Back Bay 19
2. Dark grey loamy silt, prominently stratified 12
   a. Upper 8 feet contained
      Mya arenaria c. Large.
      Ensis directus C.
      Mulinia lateralis
      Gemma gemma
      Modiolus demissus, var. plicatulus r.
      Ostrea virginica c, but comparatively small, including both current and quiet water forms. These were noted directly beneath the fill. On account of the absence of oysters between this and the stratum of large current oysters below, it is believed that these smaller oysters did not grow here but are due to man's agency.
      Mytilis edulis r
      Ilyanassa obsoleta r
      Balanus cf. balanoides r
   b. Lower 4 feet contained
      Ostrea virginica C; similar to the very large current forms so common at the Charles River locality.
      Venus mercenaria c
      Mulinia lateralis C
      Gemma gemma C
      Littorina palliata c
      Ilyanassa obsoleta C
      Nassa trivittata r
      Polinices heros r
      Crepidula plana r
      C. fornicata r
      Cliona sulphurea r. Noted on oyster shells.
      Crab claws r
      Fish vertebra R
      Besides these, Macoma balthica was abundant, but its exact position in 2 was not noted.
3. Blue glacial clay, at a depth of 31 feet. No unconformity was observed in the ten foot wide section studied.

To the west of Berkeley Street, nearly in front of the Rogers Building (M. I. T.) occurred sticks in both vertical and horizontal positions, apparently a portion of an old fish-weir. The length of the vertical ones varied according to different observers from four to seven feet. They usually penetrated the blue clay, one to a depth of eighteen

inches. Taking Mr. L. S. Stone's estimate of the greater length of seven feet, there would be from six to seven feet of silt above the sticks. For a consideration of their age there must be added to this the thickness deposited between the driving of the sticks and the deposition of sediment over their decaying ends. The wood testifies to its great age in being exceedingly brittle and very heavy, showing that a certain amount of petrifaction had occurred. Its very dark, almost black, color indicates, likewise, considerable carbonization.

f. Arlington Street.

		Feet
1.	Fill	16
2.	Black silt. A few shells are reported from near the top of this.	5
3.	Boulder clay. The boulders are well rounded, and are more numerous at the bottom of the section, where they make up fully one-half of the sediment. The boulders are usually two to three inches in diameter; the largest noted had a diameter of three feet, with corners all well rounded. This clay was not penetrated farther up Boylston Street.	17

g. Church Street. At some thirty feet below the surface of the street (which is here fifteen feet above low tide) a tree stump was excavated from near the top of a peat bed. The peat continued eighteen feet below the stump. The stump was reported as uncarbonized. Apparently another tree was encountered in a wash-boring near here.

h. Charles Street. At the Public Garden side of Charles and Boylston streets a boring penetrated a peat bed 27.5 feet thick. The bottom of the peat is 42 feet below the surface of the street, which is here 15 feet above low tide.

5. **Site of Old Providence Depot.** The following were found while excavating Providence Street:*

Mya arenaria r. Small
Ilyanassa obsoleta C.
Littorina rudis r.

6. **Commonwealth Flats, South Boston.** Peat was encountered here 20 feet below low tide.†

* Collected by Mr. E. L. Green.
† Communicated by Mr. R. W. Sayles.

7. **City Point, South Boston.** To form the Marine Park here mud was dredged from midway between Castle Island and the old City Point shore, being dumped at the edge of the latter. In this mud occurred the shells noted in the table below. The dead appearance of most shells leaves no doubt as to their fossil condition, though the excavation went to a depth of only a few feet.

List of Species.

The following list includes all post-glacial fossils noted, or listed by previous observers, from Brookline through Back Bay, Boston, to City Point.

Species x — Present C — Very common c — Common r — Rare R — Very rare	Muddy River	Charles River	Exeter Street	Berkeley Street	City Point
1. Plants (unrecognizable fragments)	x		x		
FORAMINIFERA *					
2. Polystomella striatopunctata			x		
3. P. sp.			x		
4. Trochammina inflata			x		
SPONGIA					
5. Cliona sulphurea			r	r	R
BRYOZOA					
6. Membranipora pilosa			r		
PELECYPODA					
7. Yoldia limatula					x
8. Ostrea virginica	x	C	R	c	C
9. Pecten gibbus borealis	R	C			C
10. P. magellanicus					x
11. Anomia simplex					c
12. Mytilus edulis					x
13. Modiolus modiolus			R		x
14. M. demissus var. plicatulus	x	x	r	r	x
15. Clidophora trilineata					x
16. Arctica islandica					x
17. Cyclocardia borealis					x
18. Astarte undata					x
19. A. elliptica					x
20. Lucina filosa					x
21. Kellia planulata					x
22. Laevicardium mortoni					x
23. Venus mercenaria	x	C		c	C
24. Gemma gemma			C	C	x
25. Petricola pholadiformis					x
26. Macoma balthica	C	x	C	c	x

* Identified by J. A. Cushman.

	SPECIES x — Present C — Very common c — Common r — Rare R — Very rare	Muddy River	Charles River	Exeter Street	Berkeley Street	City Point
27.	Tagelus gibbus					x
28.	Ensis directus			r	C	x
29.	Angulus tener					x
30.	Mactra solidissima					x
31.	Mulinia lateralis	C	x	C	x	c
32.	Mya arenaria	x	C	C	c	C
	GASTROPODA					
33.	Acmaea testudinalis					x
34.	A. testudinalis var. alveus					x
35.	Vitrinella shimeri Clapp			r		
36.	Turbonilla winkleyi			c	R	x
37.	Odostomia trifida			R		
38.	O. fusca			c		x
39.	O. bisuturalis			c	r	
40.	Littorina rudis	x		r		x
41.	L. rudis tenebrosa	R		r		
42.	L. palliata			r		x
43.	L. littorea *					c
44.	Lacuna vincta					x
45.	Crepidula fornicata			r	r	c
46.	C. plana			R	r	x
47.	C. convexa			R		x
48.	Polinices heros	c	x		r	x
49.	P. triseriata	x	x			c
50.	Neverita duplicata					x
51.	Paludestrina minuta			C		
52.	Bittium alternatum			R		x
53.	Triforis nigrocinctus			R		x
54.	Columbella lunata				R	x
55.	Cingula carinata				R	
56.	Buccinum undatum					x
57.	Nassa trivittata	x	x	c	r	x
58.	Ilyanassa obsoleta	C	x	C	C	c
59.	Urosalpinx cinereus	r	x	R		x
60.	Thais lapillus					c
61.	Anachis avara		x			
62.	Tornatina canaliculata	x		C	r	x
63.	Melampus lineatus	c				x
	CRUSTACEA					
64.	A copepod			x		
65.	Balanus balanoidès	x			r	
66.	B. crenatus			R		
67.	B. porcatus			x		
68.	Crab claws			r	r	
	VERTEBRATA					
69.	Fish				R	

* This species was doubtless introduced into the fossil shells by the dredge, since nowhere else upon the American coast is this shell reported earlier than 1855 (Gulf of St. Lawrence). It is apparently a late migrant from Europe.

Notes on Species.

Plants.

The peat encountered in the various sections is probably entirely of fresh water origin. After an examination of the peat from the subway at Exeter Street, Mr. G. B. Reed of Harvard University writes:

"I find no plants or remains of plants such as now grow on salt marshes or anywhere below high tide level. But what species have entered into the formation of the peat I can not determine beyond the presence of grasses and sedges, probably both tops and roots, woody roots probably of some Ericaceous plants, and fragments of wood. A large part, however, is made up of much decomposed material now unrecognizable. It has apparently, too, undergone considerable compression as all the stems are flattened."

The peat at Church Street, the deepest encountered, was also of fresh water origin, and occurred similarly beneath the black silt.

Spongia.

Cliona sulphurea.— The specimens noted at the Berkeley Street locality were almost entirely in oyster shells.

Bryozoa.

Membranipora pilosa.— This form is comparatively abundant at Exeter Street upon the larger shells of Mya arenaria, less so upon Modiolus demissus, var. plicatulus.

Pelecypoda.

Ostrea virginica.— This, our only species of oyster, is very rare at Exeter Street, being represented by but three specimens, the largest of which is only 85 mm. long by 70 mm. broad. At Charles River this shell is exceedingly abundant including both the long, narrow or so-called "current" form and the short, broad "quiet-water" form. The most usual size of the former is 230 mm. in length and 55 mm. in breadth; of the latter the length is 130 mm. and the breadth 70 mm. At Berkeley Street the very large current form is common at a depth of 27 to 31 feet. A valve of one of these, an old individual,

with a length of 140 mm. has a maximum thickness of 50 mm. At City Point the specimens are similar in size and abundance to those from Charles River. Miss Bryant figures one from here 265 mm. by 80 mm.

This oyster, as native, is now absent from Massachusetts Bay; during early colonial days it occurred only locally and then, on account of the cold air at such depths as to be exposed only at the low spring tides. A large oyster-bank was situated at the mouth of the Charles River, another at the mouth of the Mystic and probably one on the Noddles Island, now East Boston, flats.

That the large current forms flourished in Back Bay as late as the middle of the seventeenth century is shown by the following quotations (5):

"The Oisters be great ones in forme of a shoo horne, some be a foote long, these breed on certain bankes that are bare every spring tide. This fish without the shell is so big that it must admit of a division before you can well get it into your mouth." . . . . "Towards the southwest in the middle of this Bay" (i. e., Back Bay, at mouth of Charles River) "is a great Oyster-banke" . . . . "The Oyster-bankes" (referring to the same) "doe barre out the bigger ships."

In the first edition (1841) of the "Invertebrata of Massachusetts," Dr. Gould says (p. 357) "old men relate that they were accustomed to go up Mystic River and Charles River, and gather oysters of great size, before it was the custom to bring them from New York. And even now individuals of enormous size are occasionally brought from both these places, and probably might be found by special search, at any time."

The cause of this great numerical reduction since colonial days is said to be a very severe cold spell about 1780 in which the sea bottom was covered with ice, thus preventing the oysters from getting air. Another factor which aided in the destruction of some of these species, especially the oyster, from the Back Bay region was the gradual obliteration of Boston as an island by the formation of a neck uniting it with the mainland to the south. Even during late colonial days heavy seas washed over this neck into the Back Bay. Oysters need a clean substratum, such as gravel, or other shells, to which the young, the spat, may attach themselves, otherwise they will perish; and the opening across Boston neck would give the tidal currents extra strength with which to cleanse this partially enclosed region from the river muds; but that this was never so exposed to the action of waves as at City Point is shown by the occurrence of the surf-clam (Mactra solidissima) at the latter place only.

Many plantings of the oyster spat in its old home in the Charles River during recent years have resulted merely in the death of the spat.

Pecten gibbus borealis.— (This is our common scallop, the Pecten irradians of authors.) The single specimen seen from Muddy River is 26 mm. long by 25 mm. high. It is one of the common forms at the Charles River locality.

Mytilus edulis.— The edible mussel is present though apparently rare at Berkeley Street and City Point.

This species, occurring from about half tide down into comparatively deep water, was very abundant during early colonial times and was largely eaten by the colonists. Since it is a rather open coast form its rarity at the Back Bay localities is not surprising.

Modiolus modiolus.— This deep water inhabitant is represented in our Exeter Street collections by but one valve, 3 mm. long.

Modiolus demissus, var. *plicatulus.*— This is the coarse horse-mussel. It is very abundant in the superficial sediment at Muddy River. This mud was formed after the typical marine shells had been deposited and is hence comparatively recent. This species of Modiolus continued to thrive here until the completion of the dam across the tidal portion of the Charles River in 1911. Only a few, but characteristic, pieces of this shell were noted at Exeter Street.

Venus mercenaria.— The Muddy River forms are normal in size and weight; the concentric growth lines are quite strong. The Charles River and Berkeley Street specimens are similar to these and are very abundant.

The quahog, little-neck, round or hard clam, is now rare north of Cape Cod, as it apparently was during the early colonial days.

Gemma gemma.— This is the most abundant form found at Exeter Street; a specimen of average size measures 3+ mm. in length by 3+ mm. in height. It is likewise very abundant and of a similar size at Clarendon and Berkeley Streets.

The average of 10 specimens from Exeter Street gives a proportion of height to length of 1 to 1.06. The average of a similar number from Provincetown, Massachusetts is 1 to 1.15.

This greater height of the subway forms may be interpreted either as an evolution toward greater length since that time or as evidence of a slightly more unfavorable environment in the Back Bay area. This latter hypothesis is partly corroborated by the specimens of the same species from Buttonwoods, Rhode Island. Here, far up the Narragansett Bay, the average of height to length is 1 to 1.

*Macoma balthica.**— The Exeter Street shells are very abundant; they are normal in size and shape, an average sized specimen measuring 25 mm. long by 20 mm. high. Those specimens preserving the epidermis are usually bluish-black in color.

The Muddy River forms are very similar to the Exeter Street specimens, as are also the ones from beneath the Copley Plaza Hotel, and from Berkeley Street.

The average of ten specimens from Exeter Street gave 1 to 1.20 as the proportion of height to length, as against a proportion of 1 to 1.23 in specimens from Eastham, Massachusetts, the recent shell thus showing a similar lengthening to that noted in Gemma gemma.

Ensis directus.— The razor-clam, though now but little used as food, was highly esteemed by the early settlers. It is much more abundant at the Berkeley Street than at the Exeter Street locality.

Mulinia lateralis.— In the specimens from Exeter Street the average proportion of height to length was 1 to 1.17, while the larger recent shells from Woods Hole are in the proportion of 1 to 1.22.

Mya arenaria.— The common sand clam, soft clam or long-neck clam. Among specimens of this very abundant species at Exeter Street are some large ones with a length of 100 mm. and height of 55 mm. The Muddy River forms are normal in shape and size. The Charles River specimens seen average 110 mm. long by 65 mm. high; there are some 128 mm. by 80 mm. Those seen from the Copley Plaza and the numerous forms from Berkeley Street are similar to those from Exeter Street. The City Point forms are in size and abundance similar to those from Charles River.

That the long-neck clam was very abundant here during the early colonial days is shown by the following quotation (6):—

"Clames is a shell fish, which I have seene sold in Westminster for 12 pe. the skore. These our swine feeds upon, and of them there is no want; every shore is full; it makes the swine proove exceedingly, they will not faile at low water to be with them. The Salvages are much taken with the delight of this fishe, and are not cloyed, not-withstanding the plenty: for our swine we find it a good commodity."

Odostomia trifida.— A single, small (3 mm. long), well preserved specimen was noted at Exeter Street.

Odostomia bisuturalis.— The specimens from Exeter Street are small, averaging 3+ mm. in length and with a proportion of width to length of 1 to 2.

* Dall, after a careful comparison, considers the American specimens referable to the European species M. balthica.

Odostomia fusca.— The specimens from Exeter Street are small, averaging 3 mm. in length.

Turbonilla winkleyi.— An average specimen from Exeter Street measured 5 mm. long by 1.5 mm. wide at the large whorl. Its proportionate length and breadth are the same as those of some recent forms from Buzzards Bay.

Littorina rudis.— The Exeter Street forms are small; the largest is 9 mm. long. A normal young individual 10 mm. long was noted from Muddy River.

Littorina rudis tenebrosa.— The Exeter Street forms are small; the largest is 5 mm. long; two specimens retain the peculiar mottled checking so characteristic of this variety.

Littorina palliata.— Two specimens were noted from Exeter Street, the larger of which has a length of 9 mm. and a width of 8 mm.

Crepidula fornicata.— The Exeter Street specimens of this, the common Decker, vary from thin to heavy; are whitish without and within and moderately convex, with white platform. The shells noted are small; one has a length of 14 mm., a breadth of 11 mm., a height of 4 mm. with a depth of platform of 2 mm. Those from Berkeley Street and City Point are normal both in size and shape.

Crepidula plana.— Very probably this Flat Decker form is C. fornicata modified by its position. The Exeter Street shells are thin, white without and within, and flat, with white platform. The shells noted are small; one has length 10 mm., breadth 8 mm., height 1.5 mm., with depth of platform .2 mm. The Berkeley Street specimens are of normal size. Only two specimens were noted from City Point, the larger one of which had a length of 25 mm.

Crepidula convexa.— The Exeter Street specimens of the Convex Decker are small and very convex. The color outside is ashen brown, within reddish brown; the deeply seated platform is similar in color to the inside of the shell in very young (4 mm. long) specimens, lighter brown in older (11 mm. long) ones. One specimen has length 11 mm., breadth 8 mm., height 5 mm., depth of platform 2.5 mm. Another has length, 4 mm., breadth, 3 mm., height, 2 mm., depth of platform, 1 mm.

Polinices heros.— (Polinices is Montfort's original (1810) spelling of the genus.) The Muddy River specimens average 19 mm. in length by 17 mm. in width. From City Point two specimens were noted, considerably larger than those from Muddy River.

Polinices triseriata.— The single specimen noted from Muddy River was small but well preserved. Those from City Point had an average length of 23 mm.

Paludestrina minuta.— The Exeter Street specimens are small; a common form has a length of about 2.5 mm. and a width of 1.5 mm. The average of five specimens from here gives a proportion of greatest breadth to length of 1 to 1.78; of five from Danvers, Massachusetts, 1 to 1.68, an increase in breadth of the living individuals.

Bittium alternatum.— One individual was noted at Exeter Street; this is 6 mm. long and retains a few patches of its original slate color.

Triforis nigrocinctus.— Only one example, 3 mm. long, of this sinistral, granulated shell was noted at Exeter Street; it has become an ashy gray except where between the ridges it still retains some of the original dark red color.

Nassa trivittata.— The specimens from Exeter Street average 8.3 mm. in length by 4.8 mm. in width. Recent specimens from Ipswich Beach, Massachusetts, average 25 mm. by 9 mm. Living forms have thus attained a larger size and a greater proportionate width, averaging 1 to 2.8 as against 1 to 1.73 in the Exeter Street forms.

Ilyanassa obsoleta.— The forms from Exeter Street are about half the size of the normal species of this coast, averaging 12 mm. in length. The costae are likewise stronger than on the normal shell, approaching Urosalpinx cinereus in this respect; there are 10 to 17 costae present. They are most similar in every respect to the ones living at Buttonwoods, west of Warwick Lighthouse, far up the western side of Narragansett Bay, both probably owing their small size to the freshened condition of the water. The Muddy River forms are much larger, averaging in length 22 mm.

The following list of average measurements compares in size and proportion specimens of this species from several fossil and recent localities:—

Locality	Length mm.	Width mm.	Proportion of width to length
Subway, Exeter Street Post Pleistocene (brackish) *	12.4	7.9	1:1.57
Marblehead shell heap Post Pleistocene	18	12	1:1.5
Sankaty Head, Pleistocene	24.5	14	1:1.75
Buttonwoods, recent (brackish)	12	8	1:1.5
Dorchester Bay Recent (salt)	17	10	1:1.7
Marblehead Recent (salt)	18.5	10.5	1:1.76

* Collected by Professor E. S. Morse.

It is seen from the above tabulation that it is the brackish water environment which produces the narrow species. This is true, at least, for Buttonwoods and Exeter Street; we have no data for the Marblehead shell heap. The recent specimens from Marblehead and Dorchester Bay are from normal sea water, as was probably, judging from the associated fauna, also true of the Pleistocene of Sankaty Head, Nantucket. The difference is thus apparently due to environment and is not a permanent change of form due to evolution in time.

Urosalpinx cinereus.— This species is represented by one individual from Exeter Street, 6 mm. long. The average length of the Muddy River forms is 20 mm., which is likewise the length of those noted from City Point. It was not noted at Berkeley Street.

Thais lapillus.— The specimens noted from City Point have an average length of 30 mm. The revolving ridges are coarse.

Tornatina canaliculata.— An average sized specimen from Exeter Street is 2.5 mm. long by 1.5 mm. wide.

Conclusions.

The history of Boston from the closing stages of the great continental glaciers covering all of this region to the present day may be summed up in the following five stages:

1. Deposition in fresh water of mud and sand from the melting glacier; 2. Erosion by streams of some of this material after the disappearance of the glacier; 3. Growth of peat in swampy areas (2 and 3 were probably taking place at the same time as nowhere was peat noted in an erosion channel); 4. Partial submergence of the land beneath the ocean with the accumulation of mud and dead shells upon the peat beds. This record of submergence contains two distinct elements. (a) In the earlier or lower beds the marine shells indicate a warm climate similar to that off the Virginia coast at present. (b) The upper beds, and continuing to the present, where still beneath the sea, contain a marine fauna indicative of a colder climate, that of today. 5. In certain areas, as Back Bay, the raising of the land again from its ocean bed by artificial filling.

The conclusions bearing upon these five stages are noted below.

1. The deposition of the blue glacial clay, forming the base of the majority of the sections discussed above, took place probably in a body or bodies, of fresh water, since no remains of animal life are apparent in it. The clay itself, derived from a nearby melting glacier, is the

so-called glacial flour,— the material ground from its rocky floor by the stones held firmly in the base of the advancing ice. A few unidentified pieces of wood were noted in this clay.

2. After the glacier had melted away from this region, the earth was exposed to the air so that the upper layers of the clay were hardened through oxidation. During this time the region was subjected to erosion by running water as evidenced, in Back Bay, by the gullies in the surface of the clay. At the Longwood Bridge, Brookline, a sand-plain (a fossil delta deposited by glacial streams) was eroded to a depth of 37 feet.

3. During this erosive period, or at least during the latter part of it, fresh-water peat was broadly developed. The majority of sections, deep enough to penetrate the glacial clay or sands, encounter this peat immediately above the glacial sediment.

4. Subsequent to the deposition of a variable thickness of peat the land sank with reference to sea-level and a large portion of this region was submerged beneath the ocean. This period of submergence has extended to the present except where man has willed otherwise. During this time occurred the deposition of the black mud, in which were enclosed the shells and other records of the life then living in these waters.

The evidence that the peat in Back Bay furnishes in regard to the extent of this downward movement of the land is as follows: The bottom of the peat at Fairfield Street is 23 feet below low tide, at Exeter Street 15.5 feet, at Church Street 33 feet, and at Charles Street it is 27 feet. With a height of tide of 10 feet, as it was in Charles River before the construction of the tide-water dam, it would mean a submergence of this region of at least 33 plus 10, or 43 feet; and if the peat was formed far above sea-level it would mean a so much greater submergence.

The shells enclosed in the mud deposited upon the peat since its submergence beneath the sea give evidence of two climatic periods,— an earlier period (4a) warmer than the present and a later colder period (4b) extending to the present. In the Back Bay region, where alone our sections were sufficiently detailed to give exact information upon this point, the warmer period ends suddenly. In 4a the shells are very abundant, making up, in places, one-half of the deposited mass. In 4b the shells are comparatively rare. Yet there is little, if any, gradation between the two.

4a. The majority of the fossils noted in the Tabular List of Species are from this lower bed. A comparison of these, especially the shells,

with those most abundant along the entire Massachusetts coast north of Cape Cod today, shows that the climate of this region has become somewhat colder since the time this earlier fauna flourished so abundantly. This fauna, representatives of which are rare or altogether wanting off our coast today, is now dominant off the coast of Virginia, though it ranges from Cape Cod to Cape Hatteras. Of the sixty some species noted in our list, about half no longer occur north of Cape Cod, or only rarely in sheltered places, but find their perfect environment farther south. Ganong (7) mentions nine such sheltered areas, including the Gulf of St. Lawrence, Oak Bay, New Brunswick, Casco Bay, Maine, and Massachusetts Bay. Between the retreat of the glaciers from this coast and the present time a period must have occurred during which these waters were as warm as those from Cape Cod to Cape Hatteras today, and during which this Virginian fauna migrated northward.

4b. This was followed by a refrigeration of these northern waters sufficient to prevent the breeding of many of the species except within a few areas protected enough to raise the temperature of the air and water sufficiently during the summer, or breeding season, for the development of the young. (The adult can stand a much greater degree of cold than the young). Though Massachusetts Bay is one of the places in which the Virginian fauna has persisted longer than upon the less protected coast, yet even in Back Bay the shells living after the beginning of this colder period (4b) show a most remarkable decrease in both the number of individuals and the number of species of this southern fauna. Though such typical southern forms as the oyster and Mulinia lateralis persisted into 4b yet the vast majority of the Virginian fauna, including Venus mercenaria, Pecten gibbus borealis, Laevicardium mortoni, Triforis nigrocinctus and Vitrinella, had ceased to exist in the Back Bay region.

If we may judge from the Back Bay sections, this change from a warm water fauna to one characteristic of colder waters, was abrupt and was due to a corresponding alteration in climate. It is not probable that a refrigeration of the ocean waters alone could have made its influences felt so very decidedly as far inland as Back Bay. It is not likely, either, that all the differences between the more fossiliferous lower portion (4a) with its warm water fauna and the upper portion (4b), with its few fossils indicative of colder water, are due to the partial closure of Back Bay by the tidal building of Boston neck. This partial closure, bringing about a reduction in tidal scour, would, of course, cause a more rapid accumulation of sediment within the

Bay and hence relatively fewer fossils. The very great change, however, in the species represented, especially in the reduction both in number of individuals and species, would seem to imply an accompanying climatic change. That this refrigeration continued during colonial days to the present is indicated by the disappearance of oyster banks from the vicinity of Boston (Charles River, Mystic River and East Boston flats) and by the inability of planted oysters to grow here now.

5. A small thickness of sediment just beneath the "fill" may be due to the presence of dam walls built in the early part of the 19th century. In 1814 a corporation, "The Boston and Roxbury Mill Corporation," led by Uriah Coting, obtained a charter from the General Court empowering them to build a dam from the end of Beacon Street (at Charles Street) to Sewell's Point in the uplands of Brookline, with a cross dam to Gravelly Point in Roxbury (see dotted lines on map); also to made a roadway of each dam and to levy tolls for its use. It could confine tide water within this area and run mills by the water power thus created. At this time there was nothing but water and salt marsh from the foot of the Common to the uplands of Brookline. The mill dam was finished in 1821. But the tidal power, rather insufficient at the beginning for the running of the mills, was soon encroached upon, first, by the owners of bordering property filling in their land, thus restricting the area of the dam; and, especially, secondly by the building of the Boston and Providence and the Boston and Worcester Railroads across the water basin (these were incorporated in 1831). With this restriction of the tide and the increase in population this basin soon became a public nuisance and in 1852 a commission of the state legislature recommended that the property be abandoned for mill dam purposes and be filled in for building purposes. This was finally done, giving as a result the topmost 15 to 20 feet in the above Back Bay sections.

Man.— That man lived in this Boston region during the warmer climatic period following the retreat of the glaciers is evidenced by the excavation of the remnants of a fish-weir from these older sediments. This was found in the subway excavation on Boylston Street between Clarendon and Berkeley Streets, nearly opposite Rogers Building of the Massachusetts Institute of Technology. This weir consisted of interlaced vertical and horizontal sticks. The former were much the thicker; one, when wet, had a diameter of over two inches, while the latter in the same condition measured about a half inch. Some,

if not all, of the vertical rods penetrated the glacial clay, one to a depth of eighteen inches. The lowest horizontal sticks preserved were about a foot and a half above the glacial clay, and hence between two and three feet below the top of the four-foot bed containing the warm-water fauna. The vertical rods would naturally not have been driven deeper than to allow the horizontal sticks to rest upon the surface of the mud.

It is possible that there were horizontal sticks lower than this which were destroyed before they were covered by the preserving mud or had left their impress upon the vertical rods. Possibly, also, the horizontal withes were not driven deep enough to rest upon the mud surface. It would seem that one or both of these suppositions might be true. The forcing of two inch rods, bluntly and roughly sharpened by a stone ax, as the Harvard specimen shows, into the stiff glacial clay to a depth of eighteen inches, would be a difficult thing to do. Moreover a penetration of the clay to a depth of eighteen inches would suffice to support the weir. These probabilities would add, however, only about a foot and a half to the thickness of the sediment deposited since the weir was erected.

If we consider the lowest preserved horizontal sticks as originally the lowest and as resting upon the surface of the mud when erected, then about thirteen feet of shells and mud had been deposited between the time when man planted the fish-weir and when he blotted out the Bay. If we consider the probability that there was practically no silt present when the weir was erected it would mean the deposition of fourteen feet, eight inches of sediment between that time and the artificial filling of the Bay. The top of the vertical rods preserved was ten to twelve feet below the junction of the silt and fill.

How long a time was consumed in the deposition of these thirteen to fifteen feet of silt and shells is largely a matter of conjecture. It has been estimated that the Mississippi River deposits a foot of mud in two hundred years. A similar rate here would have required 2500 to 3000 years for the accumulation of this thickness. The streams in the Boston area would have carried annually much less sediment than the Mississippi. The amount retained in the Back Bay, however, would be a balance between the amount of mud delivered into this inland bay protected by many islands and the strength of the tidal scour. That the tidal scour was stronger during the existence of the warmer climatic fauna is shown by the presence in this Back Bay area of an abundance of oysters. These need a bottom free from mud or slime. A stronger tidal scour during the formation of this

lower bed is also indicated by the fact that this sediment is half composed of shells, while the upper, colder fauna bed contains much more mud in proportion to the number of shells. On the whole it may be considered as probable that the accumulation of silt here had been at least no faster than that by the Mississippi at present. This great age for the fish-weir finds corroboration in the preservation of the wood itself. It is considerably carbonized; its surface is almost black, and either wet or dry, is very brittle. Fragments of this fish-weir are preserved in a wet condition in Peabody Museum of Harvard University and in a dry state in the offices of the Boston Transit Company. Its preservation seems poorer than that of wood, 1500 years old, from a sacrificial well in Yucatan, and every bit as poor as that of wood from the ancient pile dwellings of Lake Neuchatel, Switzerland. The Swiss dwellings had practically disappeared before Roman times, 2000 years ago.

Yet other factors must enter into our consideration of the age of this fish-weir. At present a wooden pile exposed above the mud or sand is cut off within a few years, by the borings of mollusks. We must suppose, however, that the accumulation of the lower three or four feet of sediments, one-half of the mass of which consists of shells, must have been a slow process requiring more than a few years. Possibly such boring forms were absent from the Bay at that time, for none have been noted in the collections. It is usually held, too, that marine waters cause a more rapid decomposition of wood than fresh waters, not only "by reason of the abundance and variety of the attacking animal types, but also, it is said (Challenger reports: Deep-sea deposits, p. 256) on account of the greater amounts of sulphates and carbonates in sea-water, which by decomposition in the presence of organic acids facilitate the oxidation (destruction) of the plant tissue." This is corroborated by the fact that the deep sea dredgings yield vegetable remains in quantity only comparatively near lands; also that limestones (usually deposited far from land) contain slight or no records of land vegetation (8). These are, however, records of the open ocean, not of a partially enclosed bay, where the water would be brackish, the preservative powers of which would be still further increased by the flow and ebb of the tides. The preservation of wood in fossil deposits of a brackish water origin is exceedingly common; but all such wood is supposed to have been buried within a comparatively few years. In the case of the fish-weir the fossil shells indicate that parts of it extended above the encroaching sediment during the time necessary to deposit three or four feet of shells and

mud, next to suffer a striking climatic change and finally to deposit another foot or two of sediment. We can not conceive of this as taking place in a comparatively few years.

Still another factor has a bearing upon the age of the fish-weir. The surface of the street where the fish-weir was found is sixteen feet above mean low tide. Since the fill here is nineteen feet and the lowest preserved horizontal portion of the weir thirteen feet below this, the weir must have been driven into water sixteen feet deep at low tide or twenty-six feet at high tide. That is, to reach the surface of the water at high tide, at the present relation of land to ocean, and penetrate the clay eighteen inches, would require sticks twenty-nine feet long, at the least, and these sticks had a diameter of only two inches at base. Since the construction of a fish-weir under such conditions is practically impossible we must suppose that its erection took place before the land had become submerged to its present depth. If we may judge from the practice of today, the weir was erected when the region was exposed at low tide, or almost so, and covered at high tide. If so, the land has sunk sixteen to eighteen feet since man placed here his fish-weir.

While none of the above considerations yield anything definite as to years, yet they strongly indicate that the weir is old, very old.

To briefly summarize,— The remnants of the fish-weir, excavated on Boylston Street, give evidence of man in the Back Bay region of Boston, probably 2000 to 3000 years ago. He built this weir during a climatic period as warm as off the Virginia Coast at present, and upon a sinking coast. Since its erection the region has sunk sixteen to eighteen feet and suffered a refrigeration to its present climate.

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